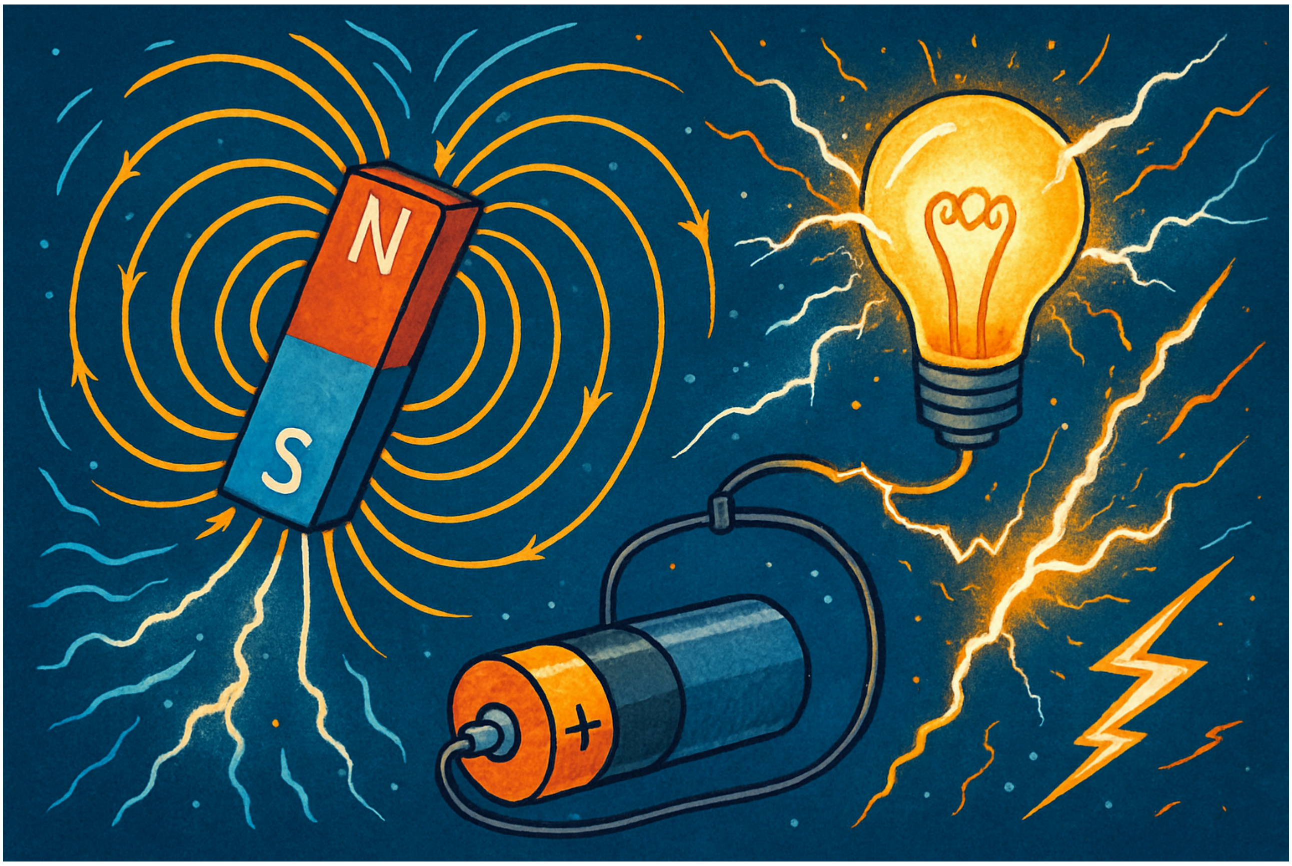
IGCSE Physics: Electricity and Magnetism

Syllabus Code: 0625



Learning Objectives

4.1 Simple phenomena of magnetism

- Describe the forces between magnetic poles and between magnets and magnetic materials, including the use of the terms north pole (N pole), south pole (S pole), attraction and repulsion, magnetised and unmagnetised
- Explain that magnetic forces are due to interactions between magnetic fields
- Describe induced magnetism

- State the differences between the properties of temporary magnets (made of soft iron) and the properties of permanent magnets (made of steel)
- State the difference between magnetic and non-magnetic materials
- Describe a magnetic field as a region in which a magnetic pole experiences a force
- Draw the pattern and direction of magnetic field lines around a bar magnet
- Know that the relative strength of a magnetic field is represented by the spacing of the magnetic field lines
- State that the direction of a magnetic field at a point is the direction of the force on the N pole of a magnet at that point
- Describe the plotting of magnetic field lines with a compass or iron filings and the use of a compass to determine the direction of the magnetic field
- Describe the uses of permanent magnets and electromagnets

4.2 Electrical quantities

4.2.1 Electric charge

- State that there are positive and negative charges
- State that charge is measured in coulombs
- State that positive charges repel other positive charges, negative charges repel other negative charges, but positive charges attract negative charges
- Describe an electric field as a region in which an electric charge experiences a force
- Describe simple experiments to show the production of electrostatic charges by friction and to show the detection of electrostatic charges
- State that the direction of an electric field at a point is the direction of the force on a positive charge at that point
- Explain that charging of solids by friction involves only a transfer of negative charge (electrons)
- Describe simple electric field patterns, including the direction of the field: (a) around a point charge, (b) around a charged conducting sphere, (c) between two oppositely charged parallel conducting plates (end effects will not be examined)

- Describe an experiment to distinguish between electrical conductors and insulators
- Recall and use a simple electron model to explain the difference between electrical conductors and insulators and give typical examples

4.2.2 Electric current

- Know that electric current is related to the flow of charge
- Define electric current as the charge passing a point per unit time; recall and use the equation $I = Q/t$
- Describe the use of ammeters (analogue and digital) with different ranges
- Describe electrical conduction in metals in terms of the movement of free electrons
- State that conventional current is from positive to negative and that the flow of free electrons is from negative to positive
- Know the difference between direct current (d.c.) and alternating current (a.c.)

4.2.3 Electromotive force and potential difference

- Define electromotive force (e.m.f.) as the electrical work done by a source in moving a unit charge around a complete circuit
- Recall and use the equation for e.m.f. $E = W/Q$
- Recall and use the equation for p.d. $V = W/Q$
- Know that e.m.f. is measured in volts (V)
- Define potential difference (p.d.) as the work done by a unit charge passing through a component
- Know that the p.d. between two points is measured in volts (V)
- Describe the use of voltmeters (analogue and digital) with different ranges

4.2.4 Resistance

- Recall and use the equation for resistance $R = V/I$
- Sketch and explain the current–voltage graphs for a resistor of constant resistance, a filament lamp and a diode

- Describe an experiment to determine resistance using a voltmeter and an ammeter and do the appropriate calculations
- State, qualitatively, the relationship of the resistance of a metallic wire to its length and to its cross-sectional area
- Recall and use the following relationship for a metallic electrical conductor: (a) resistance is directly proportional to length, (b) resistance is inversely proportional to cross-sectional area

4.2.5 Electrical energy and electrical power

- Understand that electric circuits transfer energy from a source of electrical energy, such as an electrical cell or mains supply, to the circuit components and then into the surroundings
- Recall and use the equation for electrical power P = IV
- Recall and use the equation for electrical energy E = IVt
- Define the kilowatt-hour (kW h) and calculate the cost of using electrical appliances where the energy unit is the kW h

4.3 Electric circuits

4.3.1 Circuit diagrams and circuit components

- Draw and interpret circuit diagrams containing cells, batteries, power supplies, generators, potential dividers, switches, resistors (fixed and variable), heaters, thermistors (NTC only), light-dependent resistors (LDRs), lamps, motors, bells, ammeters, voltmeters, magnetising coils, transformers, fuses and relays and know how these components behave in the circuit
- Draw and interpret circuit diagrams containing diodes and light-emitting diodes (LEDs) and know how these components behave in the circuit

4.3.2 Series and parallel circuits

- Know that the current at every point in a series circuit is the same
- Recall and use in calculations, the fact that: (a) the sum of the currents entering a junction in a parallel circuit is equal to the sum of the currents that leave the junction, (b) the total p.d. across the components in a series circuit is equal to the

sum of the individual p.d.s across each component, (c) the p.d. across an arrangement of parallel resistances is the same as the p.d. across one branch in the arrangement of the parallel resistances

- Know how to construct and use series and parallel circuits
- Calculate the combined e.m.f. of several sources in series
- Calculate the combined resistance of two or more resistors in series
- State that, for a parallel circuit, the current from the source is larger than the current in each branch
- Explain that the sum of the currents into a junction is the same as the sum of the currents out of the junction
- State that the combined resistance of two resistors in parallel is less than that of either resistor by itself
- Calculate the combined resistance of two resistors in parallel
- State the advantages of connecting lamps in parallel in a lighting circuit

4.3.3 Action and use of circuit components

- Know that the p.d. across an electrical conductor increases as its resistance increases for a constant current
- Describe the action of a variable potential divider
- Recall and use the equation for two resistors used as a potential divider V1/V2 = R1/R2

4.4 Electrical safety

- State the hazards of: (a) damaged insulation, (b) overheating cables, (c) damp conditions, (d) excess current from overloading of plugs, extension leads, single and multiple sockets when using a mains supply
- Know that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire and explain why a switch must be connected to the live wire for the circuit to be switched off safely
- Explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings

- Explain why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed
- State that a fuse without an earth wire protects the circuit and the cabling for a double-insulated appliance

4.5 Electromagnetic effects

4.5.1 Electromagnetic induction

- Know that a conductor moving across a magnetic field or a changing magnetic field linking with a conductor can induce an e.m.f. in the conductor
- Describe an experiment to show that a changing magnetic field can induce an e.m.f. in a circuit
- State the factors affecting the magnitude of an induced e.m.f.
- State that the direction of an induced e.m.f. opposes the change causing it
- State and use the relative directions of force, field and induced current

4.5.2 The a.c. generator

- Describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings and brushes
- Explain how the rotation of a coil in a magnetic field induces an e.m.f. and current
- Sketch and explain the shape of the trace on a cathode-ray oscilloscope (c.r.o.) for the e.m.f. generated in a coil rotating in a uniform magnetic field
- Describe how the induced e.m.f. can be increased

4.5.3 The transformer

- Describe the construction of a simple laminated soft-iron transformer
- Explain the principle of operation of a transformer in terms of electromagnetic induction
- Recall and use the equation $(V_p/V_s) = (N_p/N_s)$
- Know that a transformer is used to change the voltage of an alternating current
- Describe the use of step-up and step-down transformers in the large-scale generation and transmission of electrical energy

- Recall and use the equation for an ideal transformer (VpIp = VsIs)

Core Content

4.1 Simple phenomena of magnetism

Magnetic Poles and Forces

Magnets have two poles: a **North pole (N pole)** and a **South pole (S pole)**. Like poles repel each other (N-N repel, S-S repel), while opposite poles attract (N-S attract). These forces are due to interactions between magnetic fields.

Magnetic Materials and Induced Magnetism

Magnetic materials (e.g., iron, nickel, cobalt) can be magnetized. **Induced magnetism** occurs when a magnetic material is brought near a magnet, causing it to become a temporary magnet itself. Non-magnetic materials (e.g., wood, plastic, copper) are not attracted to magnets.

Permanent vs. Temporary Magnets

Feature	Permanent Magnets (e.g., steel)	Temporary Magnets (e.g., soft iron)
Magnetism	Retains magnetism after magnetizing field removed	Loses magnetism when magnetizing field removed
Strength	Can be strong	Can be strong, but easily demagnetized
Applications	Compasses, refrigerator magnets	Electromagnets, relays

Magnetic Fields

A **magnetic field** is a region around a magnet where a magnetic pole experiences a force. Magnetic field lines are used to represent these fields. They originate from the N pole and enter the S pole, never crossing each other. The direction of the magnetic field at any point is the direction of the force on a free N pole placed at that point. The strength of the magnetic field is indicated by the density of the field lines; closer lines mean a stronger field.

Uses of Magnets

- **Permanent magnets:** Used in compasses, electric motors, loudspeakers, and data storage devices.
- **Electromagnets:** Used in relays, circuit breakers, electric bells, and lifting heavy scrap metal.

4.2 Electrical quantities

4.2.1 Electric charge

Types of Charge and Interactions

There are two types of electric charge: **positive** and **negative**. Like charges repel (positive-positive, negative-negative), and opposite charges attract (positive-negative).

Units of Charge: Charge is measured in **coulombs (C)**.

Electrostatic Charging by Friction

When two different materials are rubbed together, electrons (negative charges) can be transferred from one material to the other. The material that gains electrons becomes negatively charged, and the material that loses electrons becomes positively charged. This process is called charging by friction.

Electric Fields

An **electric field** is a region around a charged object where another electric charge experiences a force. The direction of an electric field at a point is defined as the direction of the force on a small, positive test charge placed at that point. Electric field lines originate from positive charges and terminate on negative charges.

Conductors and Insulators

- **Electrical conductors:** Materials that allow electric charge (electrons) to flow easily through them (e.g., metals). They have free electrons that can move throughout the material.
- **Electrical insulators:** Materials that do not allow electric charge to flow easily through them (e.g., plastic, rubber, glass). Their electrons are tightly bound to

atoms and cannot move freely.

4.2.2 Electric current

Definition of Electric Current

Electric current (I) is the rate of flow of electric charge. It is defined as the charge (Q) passing a point per unit time (t).

Formula: $I = Q/t$

Units: Current is measured in **amperes (A)**, and charge in **coulombs (C)**. Time is in seconds (s).

Conduction in Metals

In metals, electrical conduction occurs due to the movement of **free electrons** through the metallic lattice.

Conventional Current vs. Electron Flow

- **Conventional current:** Defined as flowing from positive to negative terminals.
- **Electron flow:** The actual movement of electrons, which is from negative to positive terminals.

Direct Current (d.c.) vs. Alternating Current (a.c.)

- **Direct current (d.c.):** Current flows in one direction only (e.g., from batteries).
- **Alternating current (a.c.):** Current periodically reverses direction (e.g., mains electricity).

4.2.3 Electromotive force and potential difference

Electromotive Force (e.m.f.)

Electromotive force (e.m.f.) (E) is the electrical work done by a source (e.g., battery, generator) in moving a unit charge around a complete circuit. It represents the energy supplied per unit charge.

Formula: $E = W/Q$

Units: e.m.f. is measured in **volts (V)**.

Potential Difference (p.d.)

Potential difference (p.d.) (V), also known as voltage, is the work done by a unit charge passing through a component in a circuit. It represents the energy converted from electrical to other forms (e.g., heat, light) per unit charge.

Formula: $V = W/Q$

Units: p.d. is measured in **volts (V)**.

Voltmeters are used to measure p.d. across components and e.m.f. across sources.

4.2.4 Resistance

Definition of Resistance

Resistance (R) is the opposition to the flow of electric current. It is defined by Ohm's Law.

Formula: $R = V/I$

Units: Resistance is measured in **ohms (Ω)**.

Factors Affecting Resistance of a Metallic Wire

- **Length:** Resistance is directly proportional to the length of the wire (longer wire = more resistance).
- **Cross-sectional area:** Resistance is inversely proportional to the cross-sectional area of the wire (thicker wire = less resistance).
- **Material:** Different materials have different resistivities.
- **Temperature:** For most metals, resistance increases with temperature.

Current-Voltage Graphs

- **Resistor of constant resistance (Ohmic resistor):** The graph is a straight line through the origin, indicating that V is directly proportional to I (Ohm's Law is obeyed).
- **Filament lamp:** The graph is a curve, showing that resistance increases as current and temperature increase (non-Ohmic).

- **Diode:** Current flows only in one direction (forward bias) after a certain threshold voltage, and resistance is very high in the reverse direction.

4.2.5 Electrical energy and electrical power

Energy Transfer in Circuits

Electric circuits transfer energy from a source (e.g., cell, mains supply) to circuit components, where it is converted into other forms (e.g., light in a lamp, heat in a heater) and then dissipated into the surroundings.

Electrical Power (P)

Electrical power (P) is the rate at which electrical energy is transferred or converted. It is the product of voltage and current.

Formula: $P = IV$

Units: Power is measured in **watts (W)**.

Electrical Energy (E)

Electrical energy (E) transferred depends on power and time.

Formula: $E = IVt$ (or $E = Pt$)

Units: Energy is measured in **joules (J)**.

Kilowatt-hour (kW h)

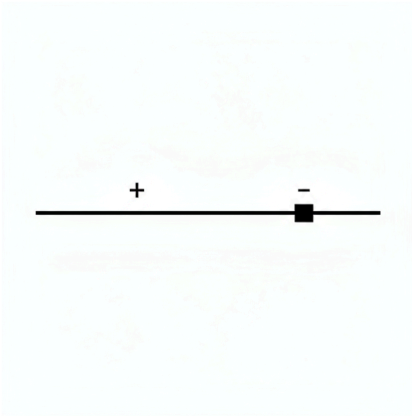
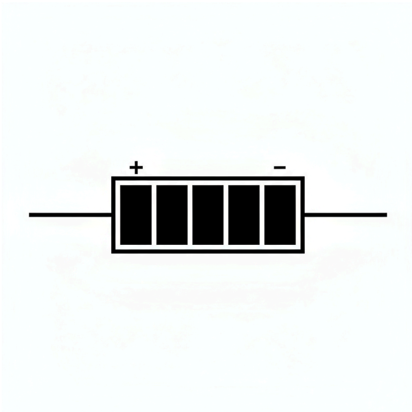
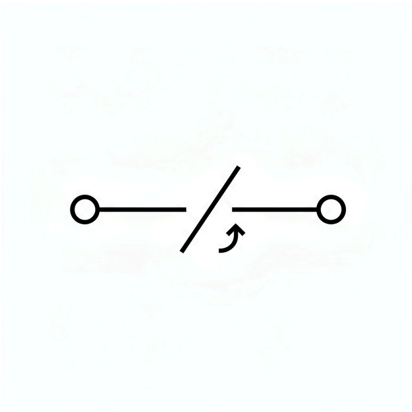
The **kilowatt-hour (kW h)** is a commercial unit of electrical energy. 1 kW h is the energy consumed by a 1 kW appliance running for 1 hour.

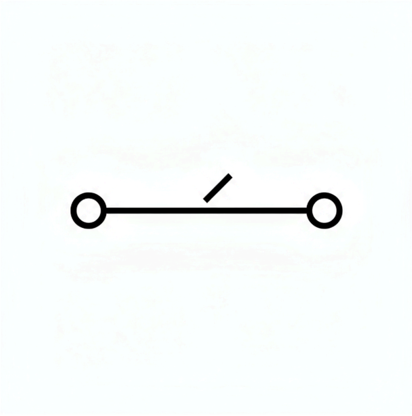
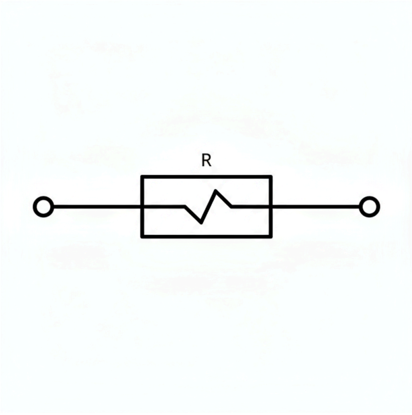
Cost Calculation: The cost of using electrical appliances is calculated by multiplying the energy consumed in kW h by the cost per kW h.

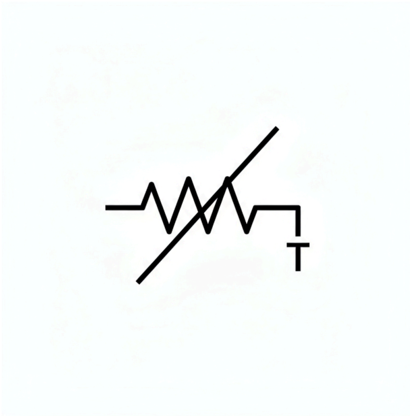
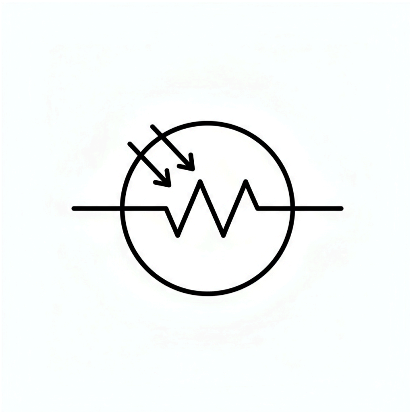
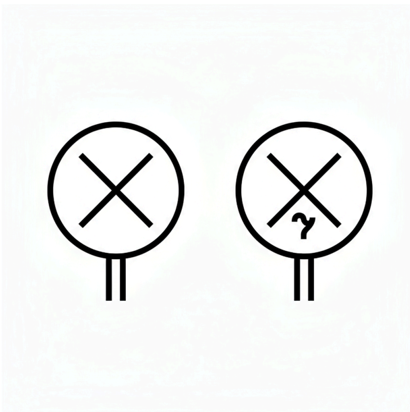
4.3 Electric circuits

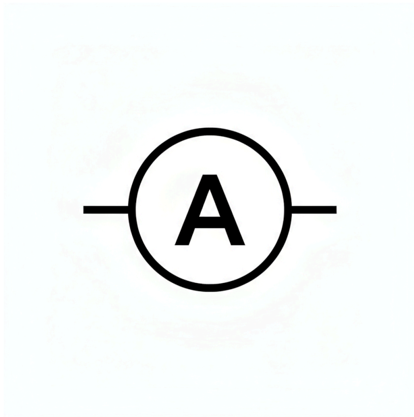
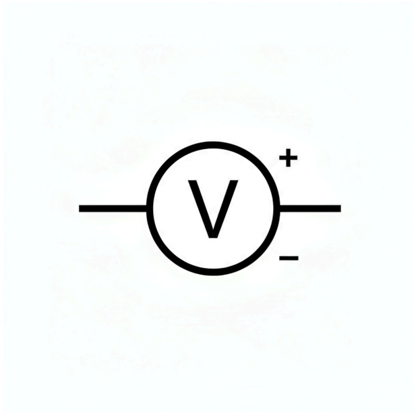
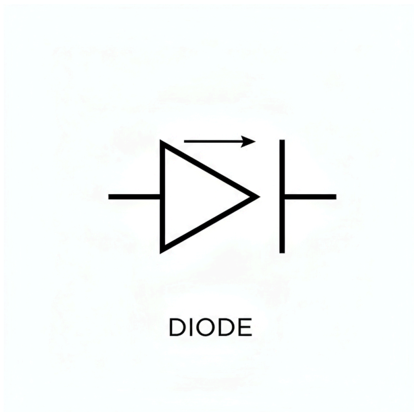
4.3.1 Circuit diagrams and circuit components

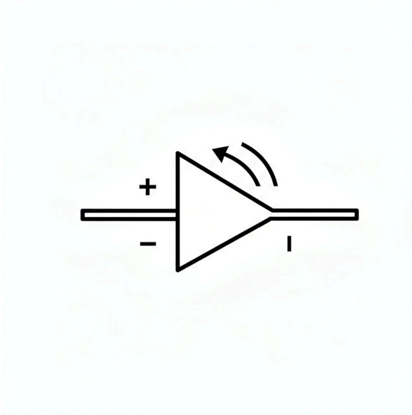
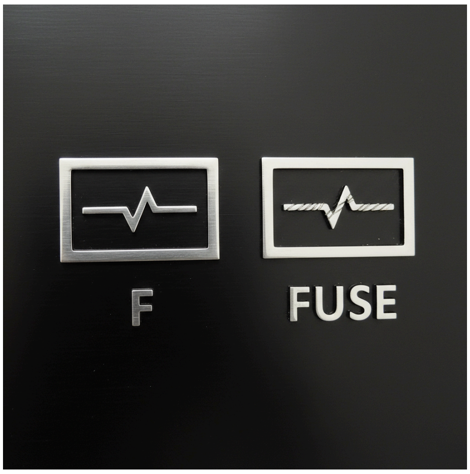
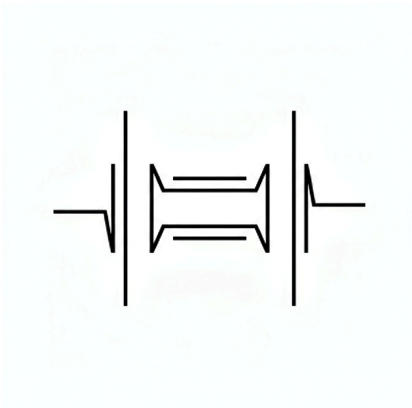
Circuit diagrams use standard symbols to represent components. Understanding these symbols and how components behave is crucial for analyzing circuits.

Component	Symbol	Behaviour
Cell		Provides e.m.f. (voltage) to drive current.
Battery		Multiple cells connected.
Switch (open)		Breaks the circuit, stopping current flow.

Component	Symbol	Behaviour
Switch (closed)		Completes the circuit, allowing current flow.
Fixed Resistor		Limits current flow; constant resistance.
Variable Resistor		Allows resistance to be changed, varying current.

Component	Symbol	Behaviour
Thermistor (NTC)		Resistance decreases as temperature increases.
LDR		Resistance decreases as light intensity increases.
Lamp		Emits light when current flows.

Component	Symbol	Behaviour
Ammeter		Measures current; connected in series.
Voltmeter		Measures potential difference; connected in parallel.
Diode		Allows current to flow in one direction only.

Component	Symbol	Behaviour
LED		Emits light when current flows in the forward direction.
Fuse 	Safety device; melts and breaks circuit if current exceeds rating.	
Transformer		Changes a.c. voltage.

4.3.2 Series and parallel circuits

Series Circuits

- **Current:** The current is the same at every point in a series circuit.
- **Potential Difference (Voltage):** The total p.d. across the components is the sum of the individual p.d.s across each component ($V_{total} = V_1 + V_2 + ...$).
- **Resistance:** The combined resistance is the sum of individual resistances ($R_{total} = R_1 + R_2 + ...$).
- **e.m.f. of cells in series:** The combined e.m.f. is the sum of individual e.m.f.s (if connected in the same direction).

Parallel Circuits

- **Current:** The sum of currents entering a junction is equal to the sum of currents leaving the junction ($I_{total} = I_1 + I_2 + ...$). The current from the source is larger than the current in each branch.
- **Potential Difference (Voltage):** The p.d. across an arrangement of parallel resistances is the same across each branch.
- **Resistance:** The combined resistance of two resistors in parallel is less than that of either resistor by itself. For two resistors, $1/R_{total} = 1/R_1 + 1/R_2$. For multiple resistors, the formula is more complex, but the principle is that adding more parallel paths decreases total resistance.

Advantages of Parallel Circuits (e.g., for lamps in a lighting circuit): * Each lamp receives the full supply voltage. * If one lamp breaks, the others remain lit. * Lamps can be switched on and off independently.

4.3.3 Action and use of circuit components

Potential Divider

A **potential divider** is a circuit that divides a voltage into smaller parts. A variable potential divider (potentiometer) can be used to provide a continuously variable output voltage.

Formula for two resistors as a potential divider: $V_1/V_2 = R_1/R_2$

4.4 Electrical safety

Hazards of Electricity

- **Damaged insulation:** Exposes live wires, leading to electric shock.

- **Overheating cables:** Can cause fires, especially if cables are too thin for the current.
- **Damp conditions:** Water is a conductor, increasing the risk of electric shock.
- **Excess current from overloading:** Plugging too many appliances into one socket can draw excessive current, leading to overheating and fire.

Mains Circuit Wiring

A mains circuit typically consists of: * **Live wire (line wire):** Carries the alternating potential difference from the supply. * **Neutral wire:** Completes the circuit; usually at or near earth potential. * **Earth wire:** A safety wire connected to the metal casing of an appliance and to the ground. It provides a safe path for current to flow if the live wire touches the casing, preventing electric shock.

A switch must always be connected to the **live wire** so that when the switch is open, the appliance is safely isolated from the high voltage supply.

Fuses and Trip Switches (Circuit Breakers)

- **Fuse:** A safety device containing a thin wire that melts and breaks the circuit if the current exceeds a certain rating, protecting the appliance and wiring from damage due to overcurrent.
- **Trip switch (circuit breaker):** An electromagnetic safety device that automatically switches off the circuit if the current becomes too large. Unlike fuses, they can be reset.

Earthing and Double Insulation

- **Earthing:** Connecting the metal casing of an appliance to the earth wire. If the live wire touches the casing, a large current flows to earth, blowing the fuse or tripping the circuit breaker, making the appliance safe.
- **Double insulation:** Appliances with double insulation have plastic casings or internal insulation that prevents any live parts from touching the outer casing. They do not require an earth wire.

4.5 Electromagnetic effects

4.5.1 Electromagnetic induction

Electromagnetic induction is the process of generating an e.m.f. (and thus current) in a conductor by changing the magnetic field around it. This can happen when a conductor moves across a magnetic field lines or when the magnetic field linking with a conductor changes.

Factors Affecting Induced e.m.f.: * **Speed of movement:** Faster movement or rate of change of magnetic field produces a larger e.m.f. * **Strength of magnetic field:** Stronger field produces a larger e.m.f. * **Number of turns in the coil:** More turns produce a larger e.m.f.

Lenz's Law: The direction of the induced e.m.f. (and current) always opposes the change that caused it.

Generators

- **Simple a.c. generator:** A coil rotates in a magnetic field, inducing an alternating e.m.f. and current. Slip rings and brushes connect the rotating coil to the external circuit.
- **Simple d.c. generator:** Similar to an a.c. generator, but uses a split-ring commutator instead of slip rings to produce a direct current output.

4.5.2 The a.c. generator

When a coil rotates in a uniform magnetic field, the magnetic flux linkage through the coil changes, inducing an e.m.f. and current. The e.m.f. induced varies sinusoidally with time, producing an alternating current. The trace on a cathode-ray oscilloscope (c.r.o.) for the e.m.f. generated would be a sine wave.

Increasing Induced e.m.f.: * Increase the speed of rotation of the coil. * Increase the strength of the magnetic field. * Increase the number of turns in the coil. * Increase the area of the coil.

4.5.3 The transformer

Transformers are devices used to change (step up or step down) the voltage of an alternating current. They consist of two coils (primary and secondary) wound around a laminated soft-iron core.

Principle of Operation: When an alternating current flows through the primary coil, it creates a continuously changing magnetic field in the soft-iron core. This changing magnetic field links with the secondary coil, inducing an alternating e.m.f. in it (electromagnetic induction).

Transformer Equation:

Formula: $V_p/V_s = N_p/N_s$

Where: V_p = primary voltage, V_s = secondary voltage, N_p = number of turns in primary coil, N_s = number of turns in secondary coil.

Types of Transformers: * **Step-up transformer:** $N_s > N_p$, so $V_s > V_p$ (increases voltage). * **Step-down transformer:** $N_s < N_p$, so $V_s < V_p$ (decreases voltage).

Transmission of Electrical Energy: Transformers are crucial in the large-scale transmission of electrical energy. Step-up transformers increase voltage for efficient long-distance transmission (reducing current and thus power loss due to heating), and step-down transformers decrease voltage for safe domestic and industrial use.

Ideal Transformer Equation (for 100% efficiency):

Formula: $V_pI_p = V_sI_s$

4.5.4 The d.c. motor

Motor Effect: A current-carrying conductor placed in a magnetic field experiences a force. The direction of this force is given by **Fleming's left-hand rule**.

Factors Affecting the Force: * **Magnitude of current:** Larger current produces a larger force. * **Strength of magnetic field:** Stronger field produces a larger force. * **Length of conductor in the field:** Longer conductor produces a larger force.

Simple d.c. motor: A d.c. motor uses the motor effect to convert electrical energy into kinetic energy. A coil carrying current is placed in a magnetic field. The forces on the sides of the coil create a turning effect (torque). A split-ring commutator reverses the current direction in the coil every half turn, ensuring continuous rotation in one direction.

4.5.5 The magnetic effect of a current

Magnetic Effect of Current: A current flowing through a conductor creates a magnetic field around it.

Magnetic Field Patterns: * **Straight wire:** Concentric circles around the wire. The direction is given by the **right-hand grip rule** (thumb in direction of current, fingers curl in direction of field). * **Flat circular coil:** Field lines resemble those of a bar magnet, with a uniform field inside the coil. * **Solenoid:** A long coil of wire. The magnetic field inside a solenoid is strong and uniform, similar to that of a bar magnet. The poles are determined by the direction of current using the right-hand grip rule.

Strength of Magnetic Field: * **Straight wire:** Directly proportional to current, inversely proportional to distance from the wire. * **Solenoid:** Directly proportional to current, number of turns per unit length, and the area of the coil.

Key Terms & Definitions

Term	Definition
Magnetic Pole	The ends of a magnet where the magnetic field is strongest (North and South).
Induced Magnetism	Temporary magnetism acquired by a magnetic material when placed in a magnetic field.
Magnetic Field	Region around a magnet where a magnetic force is exerted.
Electric Charge	Fundamental property of matter, either positive or negative, measured in Coulombs.
Electric Field	Region around a charged object where an electric force is exerted.
Conductor	Material that allows electric charge to flow easily.
Insulator	Material that resists the flow of electric charge.
Electric Current	Rate of flow of electric charge, measured in Amperes.
Direct Current (d.c.)	Electric current that flows in only one direction.
Alternating Current (a.c.)	Electric current that periodically reverses direction.
Electromotive Force (e.m.f.)	Energy supplied per unit charge by a source in a complete circuit, measured in Volts.
Potential Difference (p.d.)	Energy converted per unit charge across a component, measured in Volts.
Resistance	Opposition to the flow of electric current, measured in Ohms.
Electrical Power	Rate at which electrical energy is transferred, measured in Watts.
Kilowatt-hour (kW h)	Commercial unit of electrical energy.
Series Circuit	Circuit where components are connected end-to-end, current is same throughout.
Parallel Circuit	Circuit where components are connected across the same two points, voltage is same across each branch.

Term	Definition
Potential Divider	Circuit that divides a voltage into smaller parts.
Live Wire	Carries the alternating potential difference from the supply.
Neutral Wire	Completes the circuit, usually at earth potential.
Earth Wire	Safety wire connected to metal casing of appliance and ground.
Fuse	Safety device that melts and breaks circuit if current is too high.
Trip Switch (Circuit Breaker)	Reusable safety device that automatically switches off circuit if current is too high.
Electromagnetic Induction	Generation of e.m.f. in a conductor by a changing magnetic field.
Generator	Device that converts mechanical energy into electrical energy.
Transformer	Device that changes a.c. voltage using electromagnetic induction.
Motor Effect	Force experienced by a current-carrying conductor in a magnetic field.
d.c. Motor	Device that converts electrical energy into kinetic energy using the motor effect.
Right-Hand Grip Rule	Used to determine the direction of the magnetic field around a current-carrying wire.
Fleming’s Left-Hand Rule	Used to determine the direction of the force on a current-carrying conductor in a magnetic field.

Summary & Review

This study guide has provided a comprehensive overview of electricity and magnetism. We began by exploring the simple phenomena of magnetism, including magnetic poles, fields, and the distinction between permanent and temporary magnets. We then delved into electrical quantities, covering electric charge, current, electromotive force, potential difference, resistance, and electrical energy and power. The guide also detailed electric circuits, including circuit diagrams, series and parallel connections, and the action of various components. Electrical safety, with topics like hazards, mains wiring, fuses, and earthing, was also covered. Finally, we examined electromagnetic effects, including induction, generators, transformers, the motor effect, and the magnetic effect of a current.

Further Reading

- Save My Exams: IGCSE Physics - Electricity and Magnetism
- Physics & Maths Tutor: IGCSE Physics Notes
- Khan Academy Physics

4.5.1 Electromagnetic induction

Relative Directions of Force, Field, and Induced Current: When a conductor moves through a magnetic field, an e.m.f. is induced. The direction of this induced e.m.f. and current can be determined by **Fleming's Right-Hand Rule** (also known as the generator rule):

- **Thumb:** Direction of Motion of the conductor
- **Forefinger:** Direction of the Magnetic Field (North to South)
- **Middle Finger:** Direction of the Induced Current

This rule helps to understand how the relative directions of these three quantities are linked.

4.5.2 The a.c. generator

Simple A.C. Generator Construction and Operation: A simple a.c. generator converts mechanical energy into electrical energy. It consists of:

- **Rectangular Coil:** A coil of wire that rotates in a magnetic field.
- **Magnets:** Provide a uniform magnetic field.
- **Slip Rings:** Two metal rings that are connected to the ends of the coil and rotate with it. They provide continuous electrical contact between the rotating coil and the external circuit.

- **Brushes:** Carbon contacts that press against the slip rings, allowing the induced current to flow to the external circuit.

How it works: 1. As the coil rotates in the magnetic field, the magnetic flux linking the coil changes, inducing an e.m.f. and current in the coil (Faraday's Law of Electromagnetic Induction). 2. The direction of the induced current reverses every half rotation, resulting in an alternating current (a.c.). 3. The slip rings and brushes ensure that this alternating current is transferred to the external circuit.